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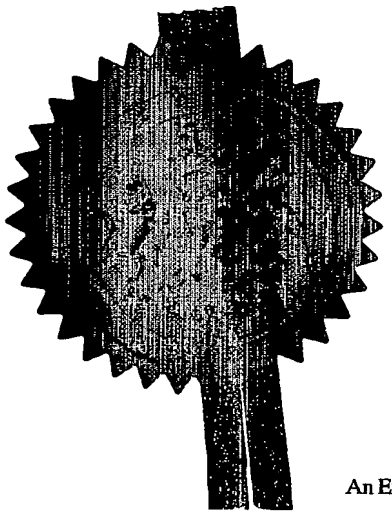

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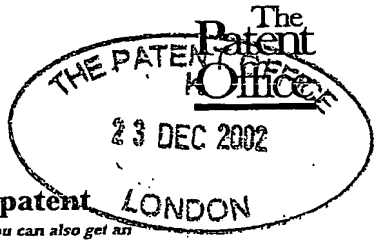

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P01/7700 0.00-0230043.2

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2. Patent application number *(The Patent Office will fill in this part)* — 0230043.2

3. Full name, address and postcode of the or of each applicant *(underline all surnames)*

BAE SYSTEMS plc

6 Carlton Gardens
London
SW1Y 5AD

Patents ADP number *(if you know it)*

07914672002 07914674004

If the applicant is a corporate body, give the country/state of its incorporation

United Kingdom

4. Title of the invention

AN APPARATUS FOR CURING A COMPOSITE LAMINATE

5. Name of your agent *(if you have one)*

"Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*

BAE SYSTEMS plc
Group IP Department
Lancaster House, P.O. Box 87
Farnborough Aerospace Centre
Farnborough, Hampshire, GU14 6YU

Patents ADP number *(if you know it)*

07914674002

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Country	Priority application number *(if you know it)*	Date of filing *(day / month / year)*

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Number of earlier application	Date of filing *(day / month / year)*

8. Is a statement of inventorship and of right to grant of a patent required in support of this request? *(Answer 'Yes' if:*

a) any applicant named in part 3 is not an inventor, or
b) there is an inventor who is not named as an applicant, or
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YES

AN APPARATUS FOR CURING A COMPOSITE LAMINATE

The present invention relates to the curing of composite materials for the manufacture of components and is particularly concerned with the control of the curing process.

Composite materials comprise fibres such as Carbon fibres, Glass fibres and Aramid fibres held in a variety of resin matrices. They are used to manufacture components for many applications and are especially common in the aerospace industry.

To form the composite material a chemical process by which the liquid resin cross-links to form a solid, known as curing, is undertaken. Curing generally takes place during component moulding although it can also take place at other stages of forming the component such as before or after moulding or commence during moulding and be completed after moulding. Curing of a component may require anything from a few seconds to several hours. Curing requires a reaction to take place in an applied system. In the aircraft industry components manufactured from composite materials require the reaction to occur at precisely controlled temperatures, (this may be room temperature or an elevated temperature), with or without pressure applied to consolidate the material.

Environmental conditions, including temperature distribution, have to be precisely controlled, to produce a uniform cure across the whole of the component. To allow the environment to be controlled curing takes place inside a temperature controlled vessel such as an oven or an autoclave (where pressure is also controlled). Other environmental conditions such as humidity may also be controlled. Controlling the temperature across the component is made more complex by design requirements that include relatively thick components and/or changes in the thickness of the composite material. These design requirements increase the difficulty in maintaining a constant temperature throughout the thickness of the composite material and at different points on the finished component. The differences in thickness across the

component means that the material does not heat up and cool down evenly, leading to hot and/or cold spots.

To control the process and know when and where more or less heat should be applied to eliminate or moderate hot and cold spots the temperature across the component is monitored. Devices such as thermocouples attached to the component edge are used to monitor temperature. However, these devices will only read the local edge temperature and give no indication of the temperature in regions of the component away from a device, such as in the centre of the component or at an edge position where a device is not attached. It is often found that there are rapid or slow heating regions (hot or cold spots) in the centre of the component due to thinning or thickening of the composite in these regions. The placing of thermocouples centrally on a curing laminate in order to monitor such heat fluctuations is not possible because the devices mark the product and this is not acceptable. In fact it is unacceptable to place any device on the surface of the component away from the edge.

The difficulties explained above can be further compounded by requirements to control the cure across the component uniformly in a harsh environment, such as high temperature and pressure as experienced in an oven or autoclave.

It is an object of the present invention to provide a method of monitoring the temperature of the component across without contact with the surface.

According to a first aspect of the invention there is provided an apparatus for curing composite material including a temperature controlled vessel in which the material is placed during curing and an infra-red temperature measuring device located remotely from the component to measure the temperature of at least part of the material during curing.

The measuring device may send temperature information to a system for controlling the temperature of the vessel that processes the information and changes the temperature as necessary.

Using a remote temperature measuring device allows the temperature of the component to be measured at points away from the edges of the

component without the risk of causing damage to the component. Thus allowing more data of the actual temperature being experienced by the component during cure to be collected and analysed and subsequently allowing the curing process to be more precisely controlled leading to a more accurate cure and thus a higher integrity component.

The measuring device may be located within the vessel or outside the vessel. Locating the device inside the vessel allows currently used autoclaves and ovens to be easily modified to take advantage of the benefits of the invention. New autoclaves and ovens can be designed and built in such a way to allow the device to be located outside the heating chamber but to still be able to detect the infra-red inside the chamber. The advantage of such designs is that the device does not have to be protected from the extremes of heat and pressure experienced in the chamber.

The temperature controlled vessel may be an autoclave or an oven, for example.

Preferably the infra-red temperature measuring device is a camera.

It is further preferred that the temperature across the whole of the material is monitored.

Monitoring the temperature across the whole area of the component allows for more accurate analysis and thus more accurate control of the curing process.

According to a second aspect of the invention there is provided a method for curing composite material including the steps of;

placing the material in a temperature controlled vessel and then,

curing the material and during the curing monitoring the taking temperature readings and monitoring the temperature of at least part of the material using an infra-red device remote from the material.

The method may also include the step of processing the temperature readings and then adjusting the temperature of the vessel to maintain a constant curing temperature.

By way of example only one embodiment of the invention will now be described with reference to the following drawings in which –

Figure 1 is a view of a protective chamber for an infra-red camera.

Figure 2a is an end view of the chamber of figure 1.

Figure 2b is a side view of the chamber of figure 1.

Figure 3 shows the thermal mapping of a test laminate analysed using the apparatus and method of this invention.

As can be seen in figures 2a and 2b, an infra-red camera 1 was placed in a protective chamber 2 to protect the camera 1 from the extremes of heat and temperature experienced within an autoclave that can typically be as high as 200°C and 8 x 10^5 N/m^2 respectively. The chamber 2 is constructed as a twin walled 3, 4 stainless steel structure having a lens of Zinc Selenide 5. Zinc Selenide is used for the lens 5 because it is transparent to infra-red, unlike ordinary glass, and thus allows infra red to pass through to the detector within the camera 1. The lens 5 is made of a special crystal 12mm thick that can withstand the temperatures and pressures experienced in the autoclave (not shown).

The chamber 2 is cooled by both water and air simultaneously to maintain the environment experienced by the camera 1 at acceptable temperature and pressure. To enable the chamber 2 to receive the cooling water, air, and data/camera control cables, an entry pipe 6 and an exit pipe 7 pass through the chamber 2 to the camera 1. Both pipes 6, 7 are constructed as flexible twin walled pipes creating an inner passage and a surrounding outer passage. The entry pipe 6 provides coolant in the form of air and water. The inner passage of the pipe 6 transports air into the chamber 2 to power air shutters and to ventilate cool air into the chamber 2. The outer passage of the pipe 6 acts as a water jacket transporting cooling water to the twin wall of the chamber. The exit pipe 7 is configured in the same way and removes the water (passing through the outer passage) and air (passing through the inner passage) when they have absorbed the heat. Cables also pass through the

inner passage of the pipe 7 allowing the camera to be controlled and data to be passed to a control system.

The control system uses software to process the data received from the camera 1. This can be done in real time or at a later date. In real-time processing and analysing the data allows cure temperatures to be controlled and the temperature of the autoclave to be adjusted as necessary. By selecting specific points on the component to be cured to take readings from (usually points expected to be hot or cold spots) and directing the camera 1 to these points, the component temperature can be measured with considerable accuracy, allowing curing to be controlled very precisely.

The camera 1 can also be used to analyse the heating up and down characteristics of the autoclave prior to the autoclave being used for curing of components. Specific points in the autoclave can be monitored through a heating cycle (up and down) to see how quickly the temperature in the autoclave responds to changes in the heat provided. Thus the change in characteristics due to the introduction of tooling and/or support structures for individual components by thermally surveying such tools and supports using the camera can be analysed. The results of the analysis can be used in the control system software when assessing when and how to change the heat supplied to the autoclave once again improving precision and accuracy of the curing of a component and allowing heating potential to be maximised. An example of environmental properties that can be changed is the rate of airflow through the autoclave as well as the airflow temperature.

The cure process of composite materials can be subject to entrapment of air causing voids not normally visible to the manufacturer until after removal from cure and only visible when subject to Non destructive testing like C-Scan. The analysis carried out in real time using the above described system can be developed to allow inspection of composite components during curing and this can be incorporated into the cure process for the real time inspection of components.

The camera 1 maybe fixed in position or moveably mounted to allow larger structures to be monitored by one camera 1.

Figure 3 shows a view of an initial test laminate 10 within an autoclave. The shading of the view indicates the differences in temperature across the laminate10. Cooler spots show up as lighter shades and hotter spots as darker shades as indicated by the temperature key 11. As can be seen the edge of the laminate 12 is cooler than the rest of the laminate 10.

Claims

1. An apparatus for curing composite material including a temperature controlled vessel in which the material is placed during curing and an infra-red temperature measuring device located remotely from the component to measure the temperature of at least part of the material during curing.

2. An apparatus according to claim 1 wherein the measuring device sends temperature information to a system for controlling the temperature of the vessel which processes the information and changes the temperature as necessary.

3. An apparatus as claimed in claim 1 or claim 2 wherein the measuring device is located within the vessel.

4. An apparatus as claimed in claim 1 or claim 2 wherein the measuring device is located outside the vessel

5. An apparatus as claimed in any preceding claim wherein the temperature controlled vessel is an autoclave.

6. An apparatus as claimed in any previous claim wherein the infra-red temperature measuring device is a camera.

7. An apparatus as claimed in any previous claim wherein the temperature across the whole of the material is monitored.

8. A method for curing composite material including the steps of;

placing the material in a temperature controlled vessel and then,

curing the material and during the curing monitoring the taking temperature readings and monitoring the temperature of at least part of the material using an infra-red device remote from the material.

9. A method as claimed in claim 8 including processing the temperature readings and then adjusting the temperature of the vessel to maintain a constant curing temperature.

10. An apparatus substantially as herein before described with reference to the accompanying drawings.

11. A method substantially as herein before described with reference to the accompanying drawings.

ABSTRACT

AN APPARATUS FOR CURING A COMPOSITE LAMINATE

An apparatus and method for controlling the curing process during the manufacture of composite laminates and components. The apparatus including a temperature controlled vessel such as an autoclave in which the material is placed during curing and an infra-red temperature measuring device such as a camera located remotely from the component to measure the temperature of at least part of the material during curing.

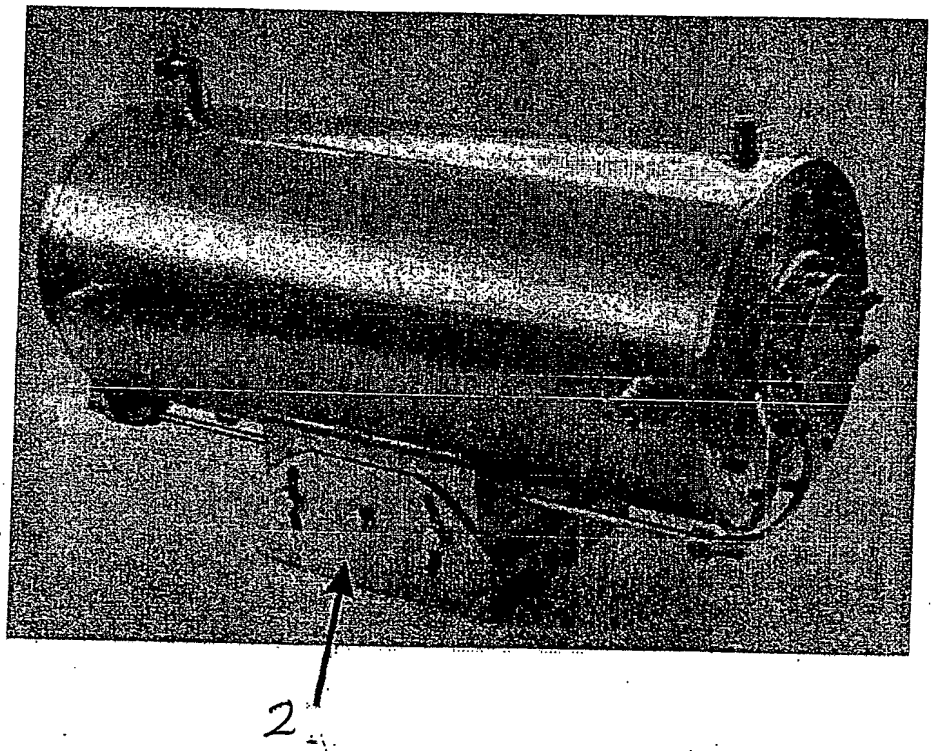

FIGURE 1

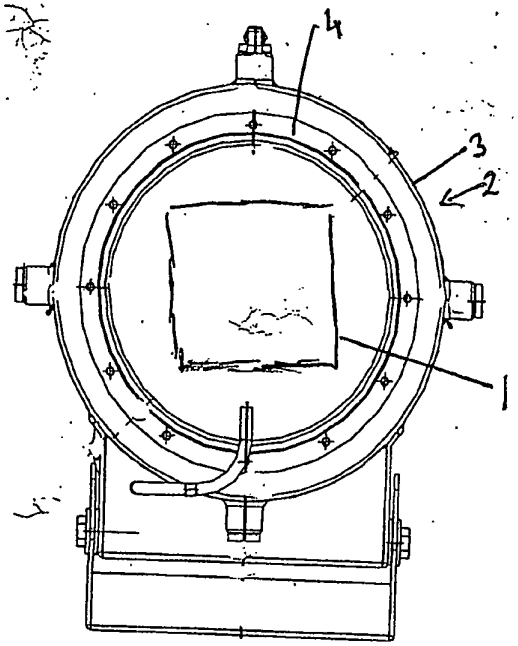

FIGURE 2a

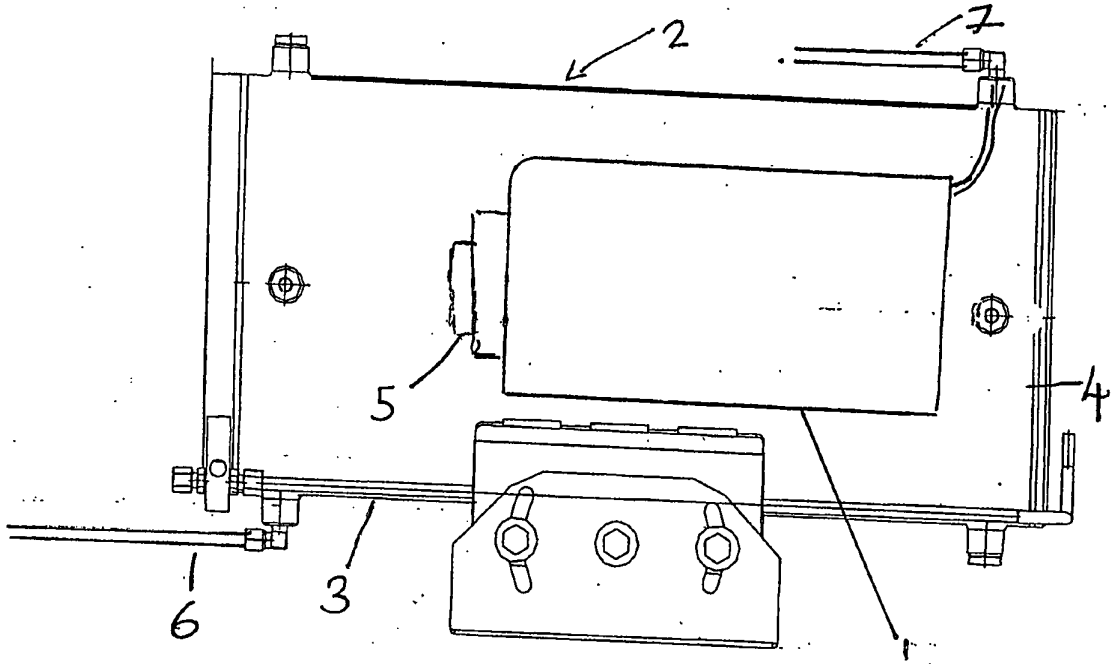

Figure 2b

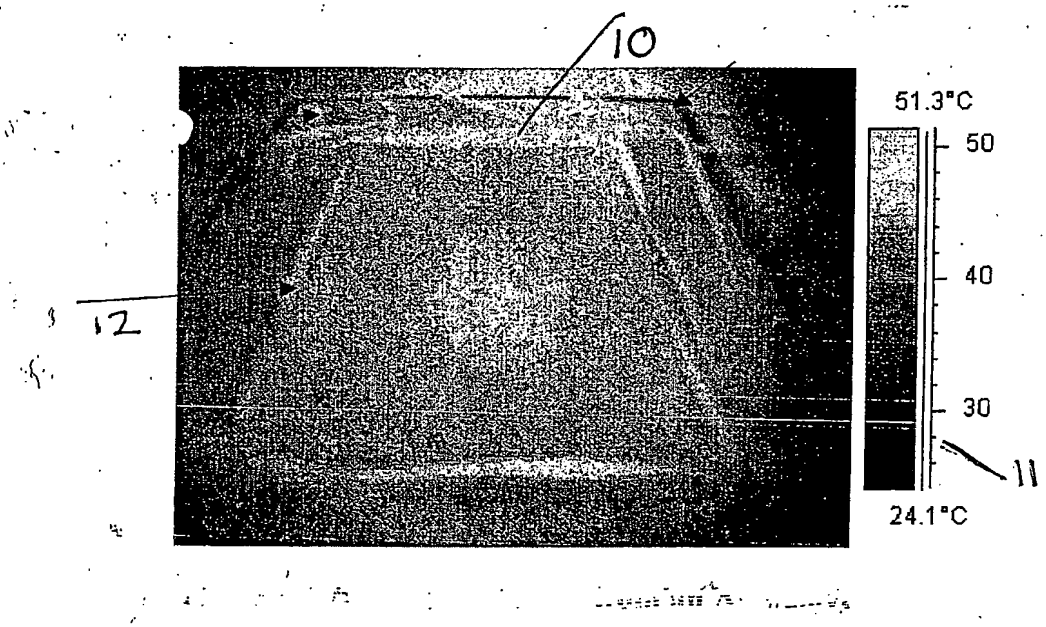

Figure 3

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